METHOD OF PROCESSING NONFERROUS METAL ALLOY AND PROCESSING APPARATUS THEREOF

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method of processing nonferrous metal alloy and an apparatus for processing nonferrous metal alloy, and more particularly to a method for processing nonferrous metal alloy such as copper alloy, aluminum alloy, magnesium alloy and the like to improve strength thereof by employing a heating process.

2. Description of the Related Art

There are several ways known to improve the strength of nonferrous metal alloy, such as copper alloy, aluminum alloy, magnesium alloy and the like. Solid solution reinforcement, transition reinforcement, intergranular reinforcement, deposition reinforcement are typical examples of improving strength thereof.

Solid solution reinforcement is a process of solidifying an element such as copper, magnesium, manganese, silicon or the like, in aluminum to achieve alloying.

Transition reinforcement is a process of cold-forming alloy to generate transition of elements in the structure thereby increasing number of crystal grating defects (transition defects) therein.

Intergranular reinforcement is a process of miniaturizing crystals and structures of alloy.

Deposition reinforcement is a process of employing a phenomenon such that deposition of alloy proceeds over a time when a supersaturated solid solution state is kept at a low temperature,

and that characteristics of the supersaturated solid solution change in accordance with temperature and time to be kept.

In order to achieve ultrahigh strength by improving conventional aluminum alloy, however, there are still problems that have to be solved.

For example, in case of employing a forming process to strengthen alloy, it is necessary to install many large and expensive rolling machines in series to be equipped with a huge and long forming line.

Further, in case of employing a heating process to strengthen alloy, it is difficult to obtain a cooling speed quickly enough to miniaturize a crystal and structure of the alloy. Likewise, there exists a limit to the cooling speed in cooling a nonferrous meta; alloy in a supersaturated solid solution state, and this cannot restrain the growth of GP zone (Guinier-Preston Zone) so that improving hardening based on an aging deposition is insufficient. Here, "GP zone" means assembly of a flat or spherical deposit scaled approximately less than or equal to 10 nanometers, which contains solute atoms in deposited solid solution being gathered at the beginning of an aging hardening of an alloy.

SUMMARY OF THE INVENTION

The present invention has been made in view of the above-mentioned circumstances and is intended to solve the above-mentioned problems. In particular, this invention provides a method of processing nonferrous metal alloy and an apparatus of processing nonferrous metal alloy capable of realizing ultrahigh strength of the nonferrous metal alloy.

The present invention provides a method of processing nonferrous metal alloy, including a step of heating the nonferrous metal alloy with liquid metal sodium at a first temperature so that nonferrous metal alloy is put in a solid solution state, and cooling the nonferrous metal alloy with a liquid metal sodium at a second temperature to suppress growth of a Guinier-Preston (G-P) zone in nonferrous metal alloy while in the solid solution state.

The present invention further provides an apparatus for processing nonferrous metal alloy, including: a first liquid metal sodium tub that stores liquid metal sodium at a first temperature and heats the nonferrous metal alloy such that the nonferrous metal alloy is put in a solid solution state, a second liquid metal sodium tub that stores liquid metal sodium at a second temperature and cools the nonferrous metal alloy to suppress growth of a Guinier-Preston (G-P) zone in the nonferrous metal alloy while in a solid solution state, and a carrier that carries the nonferrous metal alloy from the first liquid metal sodium tub to the second liquid metal sodium tub.

Further objects, features and advantages of the present invention will become apparent from the detailed description of embodiments that allows, when considered together with the accompanying figures of drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several preferred embodiments of the invention and, together with the description, serve to explain the principles of the invention.

Fig. 1 is a flowchart showing one embodiment of a method of processing nonferrous metal alloy according to the present invention.

Fig. 2 is a schematic view showing one embodiment of an apparatus for processing nonferrous metal alloy according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Preferred embodiments of a method of processing nonferrous metal alloy and an apparatus of processing nonferrous metal alloy of the present invention will now be specifically described in more detail with reference to the accompanying drawings.

Fig. 1 is a flowchart showing one embodiment of the method of processing nonferrous metal alloy. In this embodiment, nonferrous metal alloy is assumed to be a plate, however, the method can be applied if the nonferrous metal alloy is formed like a wire or other shape. Further, this embodiment teaches specific temperature conditions suitable for application to aluminum alloy; however, similar characteristics and effects can be expected if the present invention is applied to another kind of nonferrous metal alloy including copper, magnesium or the like.

In Step 1, a plate made of nonferrous metal alloy is rolled, at a given pressure, to a specific thickness by a rolling machine. This step is preferable to harden a plate, because it gives distortion in a plate that assists in generating a nucleus in the nonferrous metallic alloy when making a miniaturized structure therein. Note that Step 1 may be repeated continuously in order to obtain a plate with

a certain thickness, or may be employed as an intermediate step or a last step (followed by after-mentioned Step 7) in the whole process. As long as pressure is given to nonferrous metal alloy in Step 1, it is always effective to harden nonferrous metal alloy, even if a roller is not required.

In Step 2, dusts and impurities on the plate are removed. For example, spraying liquid such as water or solvent on the plate, or soaking the plate in a tub filled with the above-stated liquid can be employed. It is also possible to spray air onto the plate in order to expect the similar effect.

In Step 3, the plate is soaked and passed through a first liquid metal sodium to heat the plate rapidly. Preferably, the heating speed thereof may be more than 100 ℃ per second. By employing this step, alloy elements added in the nonferrous metal alloy enters a solid solution state. As a result, a lot of grating defects are formed in an almost all crystal structure of the nonferrous metal alloy due to transition in the crystal structure. In addition, growth of crystal particles is suppressed.

Note that the temperature of the first liquid metal sodium is preferably kept around 490 ℃ and is preferably controlled not to exceed 530 ℃.

Further, it is not required to employ liquid metal sodium for heating in Step 3. By employing a heating furnace such as a gas furnace, and rapidly heating the plate sufficient to make most alloy elements added in the nonferrous metal alloy enter a solid solution state as a result, the same effect as using liquid metal sodium can be achieved.

In Step 4, the plate maintained at approximately 120 ℃ is soaked and passed through a second liquid metal sodium so that the

plate is cooled rapidly soon after the heating step. For this step, crystal structures can be miniaturized while preserving the grating defects generated by Step 3 in the crystal structures of the nonferrous metal alloy. Also, the solid solution state itself changes to a supersaturated solid solution state in which segregation and concentration are restrained, in accordance with solute atoms in the solid solution state. As the result of these effects, growth of a G-P zone (Guinier-Preston Zone), in which solute atoms in the solid solution state are gathered and deposited, is suppressed.

In order to suppress growth of the G-P zone, it is effective to keep the temperature of the second liquid metal sodium as low as possible. This can provide significantly hard nonferrous metal alloy. The effect can be achieved if the temperature of the second liquid metal sodium is set lower than 200 ℃, such as about 150 ℃, for example.

In Step 5, the plate made of nonferrous metal alloy is soaked and passed through water, or water is sprayed on the plate so that the plate is cooled further to room temperature. Simultaneously, the stuck liquid metal sodium (or solidified metal sodium) used in Steps 3 and 4 is washed and removed completely. For this step, growth of the G-P zone in the nonferrous metal alloy ceases to be in the supersaturated solid solution state. Therefore, Step 5 can also increase the hardness of the plate that became significantly hard in Step 4.

In Step 6, water applied in Step 5 is dried and removed completely from the surface of the plate.

In the last Step 7, the plate is stored at a temperature approximately ranging from more than or equal to 100 ℃ to less than or equal to 200 ℃, such as by keeping the plate in a constant

temperature bath (heating tub). For this step, aging is executed, and the plate is further hardened by the effect of the aging deposition.

According to the series of steps thus explained, it is possible to provide a nonferrous metal alloy having ultrahigh strength.

Among these steps in the embodiment, employing the step of rapid heating (Step 3) and the step of rapid cooling (Step 4) can efficiently form and keep grating defects in the crystal structures. As a result, growth of a G-P zone is restrained and the plate is significantly hardened.

Further, these steps employ liquid metal sodium, which can remain in a liquid phase for a wide temperature range between approximately 100 ℃ and 800 ℃, to provide rapid heating and rapid cooling. Therefore, neither vaporization nor solidification can occur with contact to nonferrous metal alloy, and thereby stable heat transfer can be expected in the entire nonferrous metal alloy.

Such a temperature characteristic of liquid metal sodium is especially effective when nonferrous metal alloy is cooled because, employing liquid metal sodium can realize the rapid cooling to restrain growth of a G-P zone in the nonferrous metal alloy.

Consequently, a temperature gradient of the nonferrous metal alloy according to heat exchange can be controlled, and the strength of the processed nonferrous metal alloy can be fully assured.

Next, an apparatus for processing nonferrous metal alloy according to one embodiment of the present invention is explained. This embodiment, which can realize the above-explained processing method, preferably uses the same conditions, such as for temperature.

First, the plate 1 made of nonferrous metal alloy passes

through a pressing machine (Step 1) and a surface cleaning machine (Step 2), which are not illustrated, and is transferred to a heating chamber 3 through a sealed entrance 2. In the heating chamber 3, the plate 1 is guided by carriers such as a guide roller 4 and a soaked guide roller 5, and is soaked in a liquid metal sodium tub (first liquid metal sodium tub) 6 where liquid metal sodium is stored (Step 3). The plate 1 is preferably heated rapidly to more than or equal to 450 ℃.

In the heating chamber 3, inert gas such as nitrogen, argon or the like is supplied continuously to avoid a reaction of the liquid metal sodium to air. The inert gas is provided from an inert gas supply source 27a by using a pump 22a, passes through inside of the sealed entrance 2 and the heating chamber 3, and covers the liquid metal sodium tub 6. Together with evaporated liquid metal sodium, the inert gas in the heating chamber 3 is trapped by a vapor trap 23a. After removal of the evaporated liquid metal sodium, inert gas is recirculated and supplied again by the pump 22a. To allow the flow of inert gas from the sealed entrance 2 to both outside and inside, air and moisture are prevented from entering the heating chamber 3, which also prevents leakage of evaporated liquid metal sodium in the heating chamber 3 to outside.

The plate 1 pulled from the liquid metal sodium tub 6 passes through a liquid metal sodium remover 7, which sprays inert gas flow on the surface of the plate 1 to remove liquid metal sodium. The plate 1 then goes through a partition wall 31, which functions to provide thermal insulation, and is guided to a cooling chamber 8.

Similarly to the heating chamber 3, the plate 1 is also transferred by the guide roller 4 and the soaked guide roller 5 in the cooling chamber 8, and is soaked in a liquid metal sodium tub

(second liquid metal sodium tub) 9 where liquid metal sodium is stored (Step 4). The plate 1, which had been heated to a high temperature, is cooled rapidly to around 120 ℃.

Here, the cooling chamber 8 is filled with inert gas being supplied continuously, similar to that in the heating chamber 3. Inert gas is supplied by an inert gas supply source 27a by using a pump 22b, passes through the inside of a sealed exit 11 and the cooling chamber 8, and covers the liquid metal sodium tub 9. Together with evaporated liquid metal sodium, the inert gas in the cooling chamber 8 is trapped by a vapor trap 23b. After removal of the evaporated liquid metal sodium, inert gas is recirculated and supplied again by the pump 22b.

The plate 1 pulled from the liquid metal sodium tub 9 passes through a liquid metal sodium remover 10, which has the same function as the above-explained liquid metal sodium remover 7. The plate 1 is then guided to a water-cooling chamber 12 next to the cooling chamber 8 through the sealed exit 11.

In the water-cooling chamber 12, the plate 1 is soaked in a water tub 13 by using the guide roller 4 and a submerged guide roller 5a. Through heat exchange with the water in the water tub 13, the plate 1 is cooled to the vicinity of room temperature (Step 5). Here, to remove all liquid metal sodium on the plate 1, a water spray nozzle 14 connected to a washing water compressing pump 25 sprays water on both sides of the plate 1. By driving a cleaning gas compressing pump 24, inert gas is sprayed from a cleaning gas spray nozzle 29 onto the surface of the plate 1 for cleaning and drying (Step 6).

Finally, a finishing process is made on the surface of the plate 1 by using a surface finish roller 30, and the plate 1 is transferred

to outside of the water cooling chamber 12. Afterwards, the plate 1 is sent to a constant temperature bath (heating tub), not shown, for an aging process (Step 7).

In the water-cooling chamber 12, liquid metal sodium stuck on the plate 1 from the cooling chamber 8 may react to water in the water tub 13 to generate hydrogen. To discharge such hydrogen safely, a hydrogen discharge pump 15 (hydrogen remover) is connected. Further, to suppress pressure fluctuation in the water-cooling chamber 12, a buffer tub 16 (pressure fluctuation suppressor) is connected.

In the present invention, it is preferable to control physical properties of the liquid metal sodium so as to provide nonferrous metal alloy having consistently stable strength. In the liquid metal sodium tub 6 and the liquid metal sodium tub 9, however, the plate 1 and liquid metal sodium repeatedly exchange heat and the temperature of the liquid metal sodium gradually changes. Simultaneously, the purity of the liquid metal sodium is decreased due to oil, rust, dust and the like carried by the plate 1. In order to avoid this, liquid metal sodium circulator systems 37a and 37b are connected to the heating chamber 3 and cooling chamber 8, respectively.

Specifically, liquid metal sodium in the liquid metal sodium tub 6 is guided to a decontamination tub 32a to remove impurities. A storage tank 36a can refill the liquid metal sodium if necessary. Heated by a heater 34 to a certain temperature, liquid metal sodium is returned to the liquid metal sodium tub 6 again. The series of circulation is carried out by a circulation pump 33a. Similarly, liquid metal sodium in the liquid metal sodium tub 9 is guided to a decontamination tub 32b to remove impurities. A storage tank 36b

can refill liquid metal sodium if necessary. Heated by a heater 35 to a certain temperature, liquid metal sodium is returned to the liquid metal sodium tub 9 again. The series of circulation is carried out by a circulation pump 33b.

Meanwhile, the guide roller 5, which is rotated while partially contacting the liquid metal sodium, may be disabled from rotating if any liquid metal sodium is stuck to or deposited in the bearing. That is, the supporting mechanism of rotation of the guide roller 5 must be supported such that no liquid metal sodium is deposited. For this reason, as illustrated, the position of the supporting mechanism (rotating axis) of the guide roller 5 is preferably kept above the surface of the liquid metal sodium.

Liquid metal sodium carried by the plate 1 may gradually deposit in the water tub 13 in the water-cooling chamber 12. To decontaminate, a decontaminator 26 is connected.

The above-explained process apparatus is equipped with many sensors, not shown. The detected signals from the sensors are calculated by a host computer, and the process apparatus is then program-controlled in accordance with the result of the host computer.

According to the present invention, it is possible to generate and keep grating defects in crystal structure by employing a rapid heating step and a rapid cooling step. As the result, growth of a G-P zone is suppressed and the plate can be hardened. Especially by using liquid metal sodium for heat exchange with the nonferrous metal alloy, stable heat transfer can be achieved and the strength of the nonferrous metal alloy can be assured. The nonferrous metal alloy can be used as structural material for aircrafts, trains and the like.

The foregoing discussion discloses and describes merely a number of exemplary embodiments of the present invention. As will be understood by those skilled in the art, the present invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof.

Accordingly, the disclosure of the present invention is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the following claims.

Thus, the present invention may be embodied in various ways within the scope of the spirit of the invention.

The present invention does not limit nonferrous metal alloy to aluminum. Other kinds of nonferrous metal alloy such as copper, magnesium or the like can be applied to achieve the same characteristics and effects. The shape of nonferrous metal alloy is not limited to a plate, but is also applicable to wire or other shapes. Of course, the present invention is not limited to a continuous process system, in which the plate and wire are processed, but is also applicable to a batch process system for individual parts.

The entire contents of Japanese Patent Application 2002-307477, filed October 22, 2002, are incorporated herein by reference.